



World Anaesthesia Tutorial of the Week

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## **Anatomical and Physiological Changes in Pregnancy Relevant to Anaesthesia**

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Pregnancy causes major physiological changes to the mother's body. An understanding of these changes is the key to safe obstetric anaesthesia. The causes of these changes are initially hormonal; metabolic and mechanical factors also contribute as the fetus develops.

### **Endocrine Function**

The principle hormone of pregnancy is progesterone. Soon after fertilisation, the developing placenta produces human chorionic gonadotropin (hCG). This sustains the corpus luteum until the 6<sup>th</sup> to 8<sup>th</sup> week of pregnancy enabling it to produce progesterone. After this time, the placenta takes over as the main source of progesterone. The placenta also produces human placental lactogen. This has effects similar to growth hormone and may be the cause of maternal insulin resistance. It may also result in anatomical changes similar to acromegaly that are occasionally seen during pregnancy.

The thyroid gland undergoes hypertrophy during pregnancy. Increased production of thyroxine and triiodothyronine are normally balanced by increased production of thyroid binding globulin so the levels of the free hormones remain the same. Levels of parathyroid hormone tend to fall during pregnancy as does the level of serum calcium, although the level of ionized calcium remains constant due to the changes in the serum albumin concentration.

Due to the demands of the developing fetus metabolic rate increases in pregnancy. On average, 12kg weight is put on in pregnancy. This is accounted for by increases in the volumes of the plasma, interstitial fluid and amniotic fluid, as well as uterine growth, and of course the fetus. Increases in fat deposition are variable and may be used as an energy store for breast feeding in the post partum period.

## **Respiratory system**

Major physiological and anatomical changes occur in the respiratory system during pregnancy due to a combination of both hormonal and mechanical factors. Dyspnoea is a common complaint in pregnancy affecting over half of women at some stage.

Difficult intubation is said to be very much more common in the pregnant patient at term. Firstly, due to increased breast size, insertion of the laryngoscope may be difficult (a laryngoscope with an angled blade may be useful). Secondly, airway mucosal oedema (which tends to be even worse in the presence of pre-eclampsia) may make the view at laryngoscopy poor. It is recommended that a smaller size endotracheal tube is used. Nasal congestion can occur and nasal intubation is not recommended as it can result in trauma to the airways.

Hyperventilation occurs which is due both to an increase in tidal volume (40%) and a lesser increase in respiratory rate (15%). This results in a slight drop in the partial pressure of carbon dioxide (to approximately 32 mmHg or 4.3 kPa) resulting in a mild respiratory alkalosis (pH 7.44) Both the metabolic demands of the fetus and the increased work of breathing result in an increased oxygen consumption (up to 60 % during labour).

Functional residual capacity decreases by about 20 % (decreasing even further in the supine position).

The above changes in the respiratory system warrant a heightened awareness of the following factors when performing general anaesthesia.

1. Difficult intubation and a need for a range of ETT sizes.
2. Pre oxygenation is essential due to rapid de-saturation owing to an increased O<sub>2</sub> consumption and a reduction in FRC
3. Maintenance of the 'normal' lowered levels of arterial PCO<sub>2</sub> during mechanical ventilation
4. Reduced compliance necessitating higher airway pressures to maintain adequate ventilation

## **Cardiovascular system**

Cardiac output increases measurably by about 5 weeks after conception. This occurs from a combination of increased stroke volume, increased heart rate and a decrease in total peripheral resistance. Cardiac output is increased by approximately 40% at the end of the first trimester. Anatomically the heart is displaced upward and to the left by the gravid uterus. Flow murmurs are quite common due to increase plasma volume and cardiac output. Regurgitant murmurs are also not unusual due to cardiac dilatation.

The ECG reflects these changes including, left axis deviation, ST segment depression and T wave flattening.

Systemic vascular resistance (SVR) occurs due to the vasodilatory effects of progesterone and the proliferation of low resistance vascular beds in the inter-villous spaces of the placenta. Blood flow to the uterus increases to about 700ml/min by term. Blood flow to the kidneys and skin also increase whereas flow to the brain and liver remain unaltered.

Blood pressure generally falls despite the increased cardiac output due to the lower SVR. The diastolic pressure tends to fall more than systolic pressure, the maximum decline around mid gestation. Diastolic pressure may fall as much as 20 % and systolic by around 8 %

## **Aorto-caval compression**

As early as 13 weeks, the gravid uterus can compress the inferior vena cava when the woman is lying supine. Venous blood is diverted via collaterals, particularly the vertebral venous plexus to drain via the azygous system. Obstruction of the aorta occurs to a lesser degree but can result in decreased placental blood flow.

This is of great importance when positioning a patient on the operating table. During regional anaesthesia, the effects of aorto-caval compression will be exaggerated due to a lack of compensatory reflexes subsequent to the sympathetic blockade. This can lead to profound hypotension. It is usual to use either a wedge under the patient's right flank, or to tilt the operating table to the left to counteract these effects. In extreme hypotension (or fetal compromise such as a bradycardia) the patient can be turned to the full left lateral position.

## **Haematology**

The plasma volume increases up to 50% by term. Red cell volume also increases due to increased erythropoietin production, but not enough to prevent a dilutional anaemia occurring. There is a 15% drop in the measured haemoglobin. The blood viscosity is therefore also reduced which may slightly decrease cardiac work.

The platelet count tends to remain normal although there is probably an increase in their turnover. There is a steady rise in white cell count peaking during labour.

The total concentration of plasma protein is reduced due to the increase in plasma volume. This results in a drop in the colloid oncotic pressure, and may account for the oedema seen in pregnancy. Albumin levels drop to about 35 g/dl and the plasma cholinesterase levels decrease by about 25% reaching their nadir post-partum. Therefore, suxamethonium may have a slightly prolonged duration of action. The pharmacokinetics of protein bound drugs will be affected.

Coagulation is affected in pregnancy with an increase in most of the coagulation factors but also an increase in fibrinolytic activity. The result is a somewhat hyper-coagulable state. Thrombo-embolic disease is a very common condition and is one of the most important causes of maternal mortality in developed countries.

### **Renal Function**

The renal system undergoes marked changes in function during pregnancy due to hormonal effects, the increased metabolic load of the fetus and also due to outflow obstruction of the ureters by the enlarging uterus. The glomerular filtration rate increases by up to 50% in pregnancy. As a result, the clearance of urea, uric acid and creatinine all increase and their plasma concentrations are lower in pregnancy.

### **Gastric Function**

In the first trimester, hormonal changes may result in 'morning sickness'. The most extreme form of this is labelled 'hyper-emesis gravidarum' and occasionally warrants admission to hospital for iv fluid resuscitation.

In pregnancy there is a relaxation of the lower oesophageal sphincter and an increase in intra-gastric pressure due to the expanding uterus. As a result of this, the symptoms of heartburn and reflux are common in pregnancy affecting up to 70% of women. There is also an increased risk of gastric regurgitation and aspiration during induction of general anaesthesia in the later stages of pregnancy. Pregnancy itself does not prolong gastric emptying time but labour pain and any opioids administered for the pain will do so. Due to the combination of factors above, a rapid sequence induction is considered mandatory when inducing general anaesthesia in the third trimester and for 48 hours after delivery.

### **Musculo-skeletal system**

The placenta produces relaxin, a hormone that causes widespread relaxation of ligaments. This results in widening and increased mobility of the pubis and sacro-iliac joints to allow passage of the fetus through the birth canal. Pain relating to these joints may occur during the later stages of pregnancy.

Due to the enlarging uterus, there is a compensatory increase in the lumbar lordosis. As a result, backache is a common complaint during pregnancy. Back pain in the post partum

period is also very common and although there is no evidence that epidurals cause it, they are often blamed.

### **Neurological System**

The minimal alveolar concentration (MAC) of volatile anaesthetics decreases during pregnancy. This may be secondary to the high levels of progesterone and possibly an increase in B endorphin levels. There is a similar increase in sensitivity to opioids, sedatives and local anaesthetics.

The effects of local anaesthetic drugs when used for neuraxial anaesthesia and analgesia are also enhanced secondary to mechanical factors within the epidural and subarachnoid space. As mentioned earlier, compression of the inferior vena cava results in diversion of blood through the vertebral venous plexus that lies within the epidural space. This causes the epidural veins to engorge and the volume of the epidural and sub-arachnoid space to decrease. Therefore, an identical volume of local anaesthetic will spread more extensively in the pregnant than in the non pregnant state. Cannulation of an epidural vein when performing epidural insertion ('a bloody tap') is also more common.

The constituents of cerebral spinal fluid (CSF) do not change during pregnancy but its volume is reduced due to compression from the epidural veins in the epidural space. The pressure of the CSF is therefore increased. Between contractions the pressure may be around 28 mm Hg but during painful contractions it may rise to as much as 70mmHg. It is therefore probably safer not to advance an epidural or spinal needle during contractions for risk of puncturing the dura and expulsion of CSF at high pressure.

## Summary

The hormonal changes that occur from very early on in pregnancy cause a complex series of physiological and anatomical changes that affect every system of the body. To illustrate how all these changes may alter or affect anaesthetic management, it is useful to imagine performing a general anaesthetic for caesarean section and list some key points:

1. Careful attention to the assessment of the airway and any necessary preparation to deal with a potentially difficult airway in the pre operative period.
2. When positioning the patient on the table, remember to use either a left tilt of between 15 – 30 degrees on the table or a wedge under the right buttock to minimize aorto-caval compression.
3. Venous access is often easier due to engorgement of the venous system.
4. Pre oxygenation is essential and should be with a tight fitting mask for at least 3 minutes.
5. Rapid sequence induction with the application of cricoid pressure is mandatory. Intubation may be difficult and so adjuncts for difficult intubation should be available. The trained anaesthetic assistant should be careful when placing cricoid pressure if there is left tilt on the operating table as the temptation is to place the cricoid pressure straight down thus distorting the view at laryngoscopy.
6. Once the airway is secured, ventilation should be aimed to keep the  $PCO_2$  in the normal range for pregnancy.
7. The MAC of volatile anaesthetic is slightly reduced.
8. Volatile agents cause relaxation of the uterus (uterine atony) and may result in haemorrhage after delivery of the fetus.
9. There is decreased sensitivity to endogenous and exogenous catecholamines and so if vasopressors are required to maintain adequate blood pressure, the amounts needed may be greater.
10. Extubation should be done with the patient awake and on their side to reduce the risk of aspiration of gastric contents.

Using the article, answer True or False to the following questions about what occurs during a normal pregnancy:

1. A decrease in red cell mass causing a fall in the haematocrit
2. Increased oxygen carrying capacity of blood
3. Increased oxygen delivery
4. Decreased fibrinolysis and decreased level of coagulation factors
5. Decreased cardiac output in the third trimester
6. Slightly increased cardiac output during labour
7. Unchanged diastolic blood pressure
8. Decreased peripheral vascular resistance
9. Increased myocardial contractility
10. There is a marked respiratory alkalosis
11. There is a fall in arterial PCO<sub>2</sub>
12. Arterial PO<sub>2</sub> is increased
13. Minute ventilation is increased
14. Tidal volume is decreased
15. Vital capacity is increased
16. The respiratory quotient is increased
17. Arterial bicarbonate concentration is increased
18. Increased glucose filtration into glomerular fluid